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NORTHERN REGION SNAG MANAGEMENT PROTOCOL

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INTRODUCTION

Standing dead trees, or snags, long have been recognized by the scientific community for their role as critical habitat for numerous vertebrate wildlife species (McClelland 1977; Thomas et al. 1979). The Forest Service has a long record of concern for snag management. All Forest Plans in the R1-Northern Region, drafted in the late 1970s, recognized snag management as an important issue. They addressed that issue with a combination of standards and guidelines.

The Forest Service also has a long record of actions that have resulted in a loss of snags from the landscape. These actions included: 1) Long-term fire suppression that interrupted natural snag recruitment; 2) salvage programs that targeted snags, dying trees, insect mortality, and fire-killed trees; 3) short rotations that prevented the recruitment of large-diameter trees; 4) site preparation practices that largely eliminated existing snags; 5) roads and right-of-way corridors that remove both snags and recruitments, often permanently, from the landscape; and 6) utilization standards that required purchasers to drop snags not marked for retention to ensure that minimal sound material was left onsite. In addition, the Occupational Safety and Health Administration (OSHA) has imposed standards that require the felling of danger trees (often defined as snags) that pose risks to woodsworkers (OSHA 29 cfr 1910.266. Logging Operations. amended by 60 Federal Register 47035, Sept. 8, 1995).

Monitoring of timber sale-related activities (including felling, skidding, cable yarding, site preparation, and firewood cutting) consistently has shown significant losses of snags, often to below forest plan standards (USDA 1987-1996). Even where snag retention did meet forest plan standards, monitoring still generally showed significant losses from natural causes.

This document provides an optional snag retention standard specific to the Northern Region to replace the Upper Columbia River Basin interim standard (UCRB 1997) for National Forests that choose to use it. It also describes a process for the recruitment, protection, and modeling of snag management for forest plan revision. Where local data are available or are considered better than the sources used in this document, Forests have the option to use those data to set their snag retention standards.

Using this snag protocol should involve an adaptive approach to local conditions based on a scientific understanding of the disturbance ecology involved, rather than blindly following the established VRU Clusters/snag retention and recruitment standards given below.

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SNAG RETENTION RECOMMENDATIONS

Use of Vegetative Response Units (VRU) to Set Snag Retention Standards

The first step in developing snag retention standards for the Northern Region was to recognize that the natural distribution and density of snags vary across the landscape. The Upper Columbia River Basin Draft EIS (UCRB 1997) recognized this; interim standards for snag retention in the Draft EIS were radically different in warm, dry communities than in cool, wet communities.

The Northern Region will use Vegetative Response Units (VRU) as preferred categories for predicting snag density and persistence over time, instead of the more simplistic vegetative categories in the Draft EIS (UCRB 1997). A VRU is a combination of potential habitat type, fire group, and slope class. The habitat types are those described for Montana by Pfister et al. (1977) and for northern Idaho by Cooper et al. (1991). VRUs will be used as the basic building block for various resource planning analyses where predicting vegetation changes over time is a critical requirement of that analysis.

For the snag protocol, VRUs provide an excellent tool for predicting snag availability over time. The VRUs identified by the Northern Region's Vegetative Protocol Group were grouped into seven VRU clusters that best predict snag availability over time. These clusters are described and listed below in "Snag Management Recommendations by VRU Cluster" with a discussion about the typical snag occurrence expected in each.

Use of Forest Inventory and Analysis (FIA) Data to Determine Snag Densities

The next step was to use existing data to estimate the number of snags per acre expected in each of the VRUs. This differs from most past efforts to calculate snag abundance that tried to use the snag requirements of woodpeckers (Thomas et al. 1979). That technique is now known to underestimate the number of snags necessary for the many roles that snags, and later logs, play in the forest ecosystem.

To estimate snag densities, we used the Forest Inventory and Analysis (FIA) data (generally 1988-1995 data) from lands managed by the Lolo, Bitterroot, Flathead, and Kootenai National Forests, the Montana Department of Natural Resources, and private industry (see Appendix 1). FIA data were not available for northern Idaho and eastern Montana. FIA data come from fixed-radius plots of 1/2-acre in size. The data categorize snags by size (4-10.9", 11-19.9", and ≥20" dbh), with lumping of hard and soft snags. We determined snag numbers from different structure classes in each VRU structure and show them below in "Snag Management Recommendations by VRU Cluster."

One drawback to these data is the sample size variation among VRUs and structure classes. Also, 1/2-acre plots may be too small to adequately sample snags due to their patchy distribution (Bull et al. 1990). If better data are available, they should be used.

A big assumption in using these FIA data is that the data from these Montana forests can be applied to other forests within the Northern Region. Other forests lacking FIA data have the option of using other data sources (e.g., TSMRS data, special snag inventories on unmanaged mature/old forests, ECODATA), or using the interim standard (UCRB 1997).

While FIA plot data provide a good source of existing snag densities, these data do not necessarily equate to *historically available snag densities under pre-settlement conditions*. For instance, the FIA data show VRU Cluster 1 as having large densities of small diameter snags. This seems an unlikely scenario given the VRU's frequent fire regimes, but one that is explainable if we consider the 80 years of fire suppression that has typically been the case in this VRU. Another example is in VRU 7. The FIA data show a high number of large and small snags. While this seems inconsistent given the VRU's harsh growing sites and fire regime, it is explainable when we consider the combined effects of blister rust mortality on whitebark pine and fire suppression.

Snag Retention Prescriptions

"Snag Management Recommendations by VRU Cluster" describes for each VRU cluster the typical snag occurrence including spatial distribution and current deviation from the range of natural variation, and gives the recommended snag densities. "Snag Management Recommendations by VRU Cluster" is the key part of this protocol.

When determining snag retention prescriptions, we tried to avoid using data from obviously managed stands. However, some of the stands used in the analysis may have had salvage sales or single-tree selection cuts. To sort through all the noise of the variables mentioned above and get to probable historical snag densities, the team developed assumptions and interpretations, which are shown under each VRU cluster in "Snag Management Recommendations by VRU Cluster." Table 1 summarizes the range of density averages from the FIA data and the team's recommended densities.

SNAG MANAGEMENT RECOMMENDATIONS BY VRU CLUSTER

While this section gives recommended snag densities by size and species, it is recognized that current conditions may not make it possible to meet these recommendations. In that case, short-term efforts to retain all snags, even small ones or ones of a less desirable species, are preferred over no snags, and long-term plans should be initiated to return to what should be the more typical snag occurrence.

The conditions given are those that would be expected under fire regimes and insect/disease occurrences that are within the range of natural variation. Habitat types are those given in Pfister et al. (1977) and Cooper et al. (1991).

Table 1. Range of snag densities by VRU cluster and snag density retention recommendations by VRU cluster. VRU clusters are described in "Snags by Vegetative Response Unit." Data are from Appendix 1.

VRU Cluster	Range of averages of snags/ac from FIA data	Adjusted snag/acre retention prescriptions (see assumptions listed below by VRU cluster)
1	0.6-1.6 (large snags only)	1-2 >20" dbh
2	0.8-5.1	4 > 20" dbh
3	3.6-7.8	6-12 total, w 2-4 > 20" dbh
4	6.2-11.8	6-12 total w/ 2 > 20" dbh
5	9.4-12.1	12 total w/ 4 > 20" dbh
6	6.1-9.5	5-10 >10" dbh
7	1.3-3.7	all available

VRU Cluster 1--Warm, dry ponderosa pine, Douglas-fir

Habitat Types - 110 through 230, 320 through 370

Slopes - 0-60%+

Historical Disturbance Regimes - This VRU Cluster historically had an understory fire regime with fire-return intervals of 15 to 25 years. This fire regime maintained an open savannah of uneven age ponderosa pines and a few Douglas-fir, with large old trees being common. This VRU rarely had stand-replacement fires. Diseases and insects (western pine beetle, annosum root disease) caused individual scattered mortality with occasional group mortality.

Typical Snag Occurrence - Very low densities (savannah) of large ponderosa pine and Douglas-fir, persisting for long periods. Frequent, non-lethal fires result in stands that tend to be quite old and of uneven age. Mortality occurs sporadically and produces a low density of snags. Scarring and pitch buildup in ponderosa pines are common due to the repeated low intensity fires, so when these trees die, the high pitch content in the butt log resists rot. Therefore, snags are in low densities and persist for decades, even up to a century or more in some cases. With an understory fire regime, snags can occur as individuals or small groups or in patches (2-50 ac), depending on the pattern of intensity within fires. Snags created by western pine beetle and annosum root disease are scattered with occasional groups of snags. Trees killed by western pine beetle tend to be long-lived snags (50-100 years; Smith and Arno 1999), compared to the root disease snags.

Current deviation from the range of natural variation - Current conditions, because of past even-aged management, overstory removals, and fire suppression, have created different types of snag conditions. Sometimes, dense growth of ponderosa pine and Douglas-fir are predisposed to beetle attacks and stand-replacement fires, creating a boom-and-bust cycle of short-lived snags. In other cases, stands of relatively young and small firs left after overstory removal are ripe for root rot, beetles, or stand-replacement fire, resulting in short-lived Douglas-firs with small dbh. Both cases have led to longer regeneration periods (>50 years), which means very long periods without snags.

Recommended snag densities - 1 to 2 snags per acre at least 20" dbh.

Assumptions and interpretations:

The team only considered FIA structural classes 2 and 3, because only these reflected historically available conditions.

The team ignored the small and medium snags in the FIA data, as these were considered artifacts of fire suppression.

VRU Cluster 2--Cool Douglas-fir, warm grand fir on gentle slopes

Habitat Types - 250 through 319, 505, 506

Slopes - 0-30%

Historical Disturbance Regimes - This VRU is more productive than VRU Cluster 1. There are more trees per acre than in VRU Cluster 1 and the main tree species present includes western larch, ponderosa pine, grand fir, and Douglas-fir. These habitat types had a mixed fire regime, with more understory fire than stand-replacing fire. The fire-return interval was 20 to 40 years. Diseases and insects (western pine beetle, Douglas-fir beetle, annosum root disease) caused individual scattered mortality with occasional group mortality.

Typical Snag Occurrence - Moderately low densities of large ponderosa pine or Douglas-fir with some western larch, persisting for long periods. The ponderosa pines and larch are the most important species for snags because of their longevity. With an understory fire regime, snags can occur as individuals or small groups or in patches (2-50 ac), depending on the pattern of intensity within fires. Snags created by western pine beetle and annosum root disease are scattered, with occasional groups of snags. Trees killed by western pine beetle tend to be long-lived snags, compared to the root disease snags.

Current deviation from the range of natural variation - similar to VRU Cluster 1.

Recommended snag densities - 4 snags per acre at least 20" dbh, western larch and ponderosa pine where available, Douglas-fir as a second choice if not.

Assumptions and interpretations:

The team only considered FIA structural classes 2, and 3, as only these reflected historically available conditions.

The team ignored the small and medium snags in the FIA, as these were considered artifacts of fire suppression.

Most of the FIA data plots suggested the upper end of the range better reflected historic conditions, which is why 4 snags/ac were selected over 3, which was the median.

VRU Cluster 3--Cool Douglas-fir, warm grand fir on steep slopes

Habitat Types - 250 through 319, 505, 506

Slopes - 30-60%+

Historical Disturbance Regimes - This VRU Cluster experienced a mixed fire regime of stand-replacing fires or partial stand-replacing fires, with burned areas ranging from 10s to 1,000s of acres. The fire return interval was 80-200 years. The main tree species present include Douglas-fir, grand fir, western larch; occasionally ponderosa pine occurs in some of the habitat types. Douglas-fir beetles and fir engraver beetles caused group mortality. Root disease, dwarf mistletoe, and stem decays caused scattered individual mortality. Dwarf mistletoe created brooms in living trees, which provided habitat for some animal species.

Typical Snag Occurrence - High densities (pulses) of western larch or Douglas-fir (and occasionally ponderosa pine), persisting for short periods after stand-replacing or partial stand-replacing fires, with low densities of larch snags persisting for potentially very long periods. Larger snags often break off leaving a shorter staub that deteriorates from there. Large areas of snags created in the landscape (10s to 1,000s of acres). Douglas-fir beetle causes group mortality in larger diameter fir trees, resulting in snags with possibly medium longevity. The fir engraver beetle causes group mortality (20 trees/group), affecting all size/age classes of grand firs, with larger groups being prevalent during drought; snags tend to be short-lived (< 20 years). Root disease causes individual and patch mortality in all size and age classes of firs and snags are short-lived. Dwarf mistletoe top-kills large Douglas-fir and western larch trees and causes direct mortality in large and small trees, resulting in snags with medium longevity. Stem decays cause scattered individual mortality in old-growth stands and snags tend to be medium- to long-lived (>20 years).

Current deviation from the range of natural variation - Fire suppression/overstocking results in stress, producing conditions that predispose Douglas-fir and grand fir to bark beetle attacks, especially during drought periods. Although stand-replacing and partial stand-replacing fires, and mortality from insects and diseases are normal processes in this VRU Cluster, fire suppression and certain logging practices have changed the amount and distribution of these components in the landscape. This was done through high-grading of western larch and ponderosa pine, and by favoring dense, multi-storied forests over single-cohorts or simpler structural classes.

Recommended snag densities - Range of 6 to 12 snags per acre, with one-third (2-4) at least 20" dbh; western larch and ponderosa pine where available, Douglas-fir as a second choice if not.

Assumptions and interpretations:

The team only considered FIA structural classes 1, 2, and 3, as only these reflected historically available conditions.

Because of the mixed fire regime and the occurrence of "pulses" of small and medium snags, medium snags also were considered in the prescription. Although some of the small snags (those ≥8" dbh) would be useful to some species of wildlife, there was no way to separate those out of the data. Small snags were also ignored because of longevity concerns.

The team felt that fire suppression had reduced the recruitment of larger snags, and therefore increased the number of large snags slightly. This resulted in an increase in the range of snags/acre recommended.

VRU Cluster 4--Cool, wet, and dry spruce, grand fir, hemlock, and subalpine fir

Habitat Types - 410 through 480, 510 through 529, 565 through 674

Slopes - 0-60%+

Historical Disturbance Regimes - This VRU Cluster experienced stand-replacing fires with some intermediate fire regime mixed in, with burned areas ranging from 10s to 1,000s of acres. The fire return interval was 80 to 200 years. The main tree species are Engelmann spruce, grand fir, western hemlock, and subalpine fir, western larch, and Douglas-fir. Douglas-fir beetles and fir engraver beetles caused group mortality. Root disease, dwarf mistletoe, and stem decays caused scattered individual mortality. Dwarf mistletoe created brooms in living trees, which provided habitat for some animal species.

Typical Snag Occurrence - High densities (pulses) of larch or Douglas-fir, persisting for short periods after stand-replacing fires, occasionally with low densities of larch snags persisting for potentially very long periods. Also high densities of other species of snags, but these are of lower value to wildlife because they are small diameter, do not remain standing for long, or are not selected by cavity-dependent species. Some intermediate fire regime is also mixed in. Large areas of snags created in the landscape (10s to 1,000s of acres). Douglas-fir beetle causes group mortality in larger diameter Douglas-fir trees, resulting in snags with possibly medium longevity. The fir engraver beetle causes group mortality (20 trees/group), affecting all size/age classes of grand firs, with larger groups being prevalent during drought; snags tend to be short-lived. Root disease causes individual and patch mortality in all size and age classes of firs and snags are short-lived. Dwarf mistletoe top-kills large Douglas-fir and western larch trees and causes direct mortality in large and small trees, resulting in snags with medium longevity. Stem decays cause scattered individual mortality in old-growth stands and snags tend to be medium- to long-lived.

Current deviation from the range of natural variation - Fire suppression/overstocking results in stress, producing conditions that predispose Douglas-fir and grand fir to bark beetle attacks, especially during drought periods. Although stand-replacing and partial stand-replacing fires, and mortality from insects and diseases are normal processes in this VRU Cluster, fire suppression and certain logging practices have changed the amount and distribution of these components in the landscape. This was done through high-grading of western larch and ponderosa pine, and by favoring dense, multi-storied forests over single-cohorts or simpler structural classes.

Recommended snag densities - Range of 6 to 12 per acre, with 2 per acre at least 20" dbh; western larch when available.

Assumptions and interpretations:

The team only considered FIA structural classes 1, 2, and 3, as only these reflected historically available conditions.

Because of the mixed fire regime and the occurrence of "pulses" of small and medium snags, medium snags also were considered in the prescription. Although some of the small snags (those ≥8" dbh) would be useful to some species of wildlife, there was no way to separate those out of the data. Small snags were also ignored because of longevity concerns.

Because large, durable snags were limited to western larch, the large snag prescription was assumed to be fairly low.

VRU Cluster 5--Low elevation cedar, hemlock

Habitat Types - 530 through 560

Slopes - 0-60%+

Historical Disturbance Regimes - This VRU cluster experienced stand-replacing fire and intermediate fire regimes. The fire return interval was 80 to 200 years. The main tree species present are western red cedar, western larch, western hemlock, grand fir, white pine, and Douglas-fir. Mountain pine beetle and root disease caused individual, scattered mortality of white pine, and root disease kills Douglas-fir and grand fir. Stem decays affected most of the tree species. Dwarf mistletoe caused mortality in Douglas-fir and western larch.

Typical Snag Occurrence - High densities of western red cedar, western larch, grand fir, white pine, and Douglas-fir snags, persisting for moderate periods after stand-replacing fires, with moderate densities of larch, cedar, or white pine snags persisting for potentially very long periods. Some intermediate fire regime is also mixed in. Mountain pine beetle causes individual scattered mortality of white pine, with occasional small outbreaks; snags have medium longevity. Root disease causes individual mortality of white pines when mixed in with infected Douglas-fir and true firs, resulting in short-lived snags. Stem decays in western hemlock and western red cedar cause heavy decay and scattered individual mortality in older trees and stands; snags have medium longevity. Dwarf mistletoe top-kills large Douglas-fir and western larch trees and causes direct mortality in large and small trees, resulting in snags with medium longevity.

Current deviation from the range of natural variation - The introduced white pine blister rust causes landscape-level mortality of white pines, affecting all size/age classes. Larger snags will have medium longevity, while smaller ones will have short longevity.

Recommended snag densities - Average 12 snags per acre with 4 snags per acre at least 20" dbh; western larch when available.

Assumptions and interpretations:

The team only considered FIA structural classes 1, 2, and 3, as only these reflected historically available conditions.

Because of the mixed fire regime and the occurrence of "pulses" of small and medium snags, medium snags also were considered in the prescription. Although some of the small snags (those

≥8" dbh) would be useful to some species of wildlife, there was no way to separate those out of the data. Small snags were also ignored because of longevity concerns.

The FIA data are very consistent, unlike the other VRUs, so no range of snag retention is included in the small snag prescription.

Longevity of large western red cedar snags suggests that a number slightly higher than the FIA data better reflects historical density.

VRU Cluster 6--High elevation spruce/fir/lodgepole pine

Habitat Types - 675 through 790, 920, 930, 940, 950

Slopes - 0-60%+

Historical Disturbance Regimes - This VRU Cluster experienced a stand-replacing fire regime. Understory, non-lethal fires were rare except on flat benches. The main tree species present are Engelmann spruce, subalpine fir, and lodgepole pine, with some Douglas-fir. The fire return interval was 30-100 years. Mountain pine beetle and spruce bark beetle populations sometimes erupted in epidemics that caused widespread mortality. Dwarf mistletoe affected lodgepole pine and Douglas-fir, and root diseases caused individual mortality of lodgepole pines and other species.

Typical Snag Occurrence - This type is above the elevation of larch. Snags occur in pulses of high density subalpine fir, spruce, lodgepole pine, and occasionally Douglas-fir, persisting for short periods (5 to 25 years), then are gone until the next fire. This occurs after stand-replacing fires or epidemic outbreaks of mountain pine beetles or spruce bark beetle. In some areas, there is a double-burn scenario, killing off young lodgepole pines before they are old enough to produce cones; this results in areas in the landscape with no snags for even longer periods. Snags can occur over extensive areas (10s to 1,000s of acres). Rarely has an understory fire regime except on flat benches. There may also be a continuous supply of subalpine fir snags from spruce bark beetle or root disease, although these also are short-lived snags. Snags may also occur at high densities in the occasional stand that is missed repeatedly by lethal wildfires, or survives an understory burn, and achieves old growth status. Dwarf mistletoe kills the tops of lodgepole pines with some mortality of large and small trees; these snags have a medium longevity. Root disease causes individual mortality of lodgepole pines when mixed with infected Douglas-fir or true firs; these snags are short-lived.

Current deviation from the range of natural variation - Fire suppression efforts during the past 60 years have set the stage for mountain pine beetle epidemics in lodgepole pine on an unprecedented scale. This creates very high numbers of snags and subsequent fuel loadings during the next 2 decades, setting the stage for extremely large stand-replacement fires unless salvage is done to reduce the fuel loading. Fire suppression has allowed for an increase in subalpine fir and thus an increase in root disease and western balsam bark beetle activity. The introduced balsam woolly adelgid attacks subalpine fir and causes both individual and group mortality with short-lived snags.

Recommended snag densities - 5 to 10 snags per acre, leaving the largest snags available; Douglas-fir when available.

Assumptions and interpretations:

The team only considered FIA structural classes 1, 2, and 3, as only these reflected historically available conditions.

Because of the stand-replacing fire regime and the occurrence of "pulses" of snags, and the lack of any durable snag species, there is no large snag (>20" dbh) requirement.

Longevity of snags in this situation is assumed to be of short duration, but it is also difficult to predict. In some eastside situations, Douglas-fir may last for a long time, and some local revision in these prescriptions may be appropriate depending on the availability of local information.

VRU Cluster 7--Whitebark pine/limber pine

Habitat Types - 810 through 870, 91, 910, and 92

Slopes - 0-60%+

Historical Disturbance Regimes - This VRU Cluster experienced infrequent fires that were typically of low intensity.

Typical Snag Occurrence - Scattered whitebark and limber pine snags persisting for very long periods. Low intensity fires take the subalpine fir and leave the whitebark pine.

Current deviation from the range of natural variation - Current high densities of whitebark pine snags are the effect of white pine blister rust, and not typical of historic conditions.

Recommended snag densities - Save all snags. Prohibit firewood harvest.

Assumptions and interpretations:

Whitebark pine blister rust has created such conditions so far outside the range of natural variation that the FIA data are meaningless for predicting snag densities.

Lacking meaningful FIA data, the team suggested a prescription of "save all large snags."

RECRUITMENT OF SNAGS

Obviously, just protecting *existing* large diameter snags will not assure long-term snag occurrence on National Forest lands. Managing live trees for long-term snag recruitment is as important as protecting existing snags (Thomas et al.1979, Hitchcox 1996). This chapter describes a method/model, called SnagPop, for determining recruitment levels. Use of the model and its mathematical rationale are described more fully in Appendix 2.

Recruitment rates in the SnagPop model are based on the following three variables:

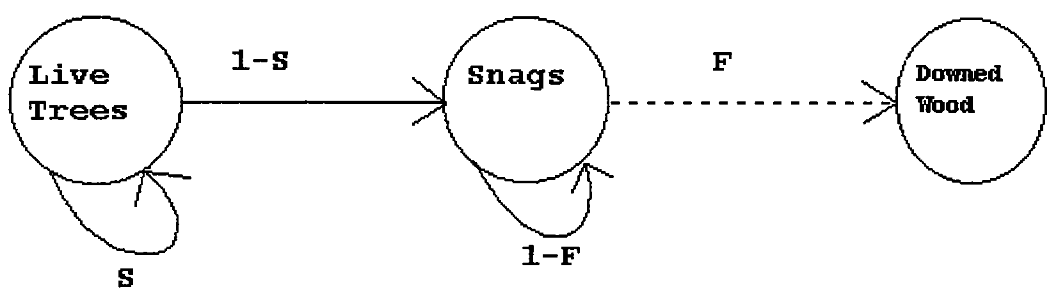
- Live Tree Survivorship Rates, or the predicted rate at which trees of a given species die;

- Snag Fall Rates, or the predicted rate at which snags of a given species fall; and

- Stem Decay Multiple, a multiple that could be assigned to elevate the snag recruitment prescription to ensure that snags have adequate levels of stem decays (a process considered essential for nesting and foraging pileated woodpeckers; McClelland 1977). However, the stem decay rate coefficient in the model currently is set at 1.0, giving it no meaning in the model at this time, because current data suggest stem decay rates are adequate to ensure that randomly selected live tree recruitments will contain reasonable amounts of stem decay after death (see Appendix 2).

The sources of data for the model are described in Appendix 2. If better local data are available, those should be used.

SnagPop Model Summary
SnagPop is a matrix population model that plots the number of live trees and number of snags per unit area over time. The life cycle graph below represents the model.



There are two stages in the life cycle of a snag represented in the model: live trees and snags. Live trees either remain live trees or become snags. Snags either remain snags or fall and become downed wood. Downed wood is implicitly modeled as snags that do not survive. Live trees survive at a given survivorship rate (S) and die and become snags at the rate (1- S). Snags fall at a given rate (F) and remain snags at the rate (1-F).

SnagPop uses the following equations to calculate the number of live trees and snags each year.

$$[\text{Live Trees}]_{t+1} = S^*[\text{Live Trees}]_t$$

$$[\text{Snags}]_{t+1} = (1\text{-}S)^*[\text{Live Trees}]_t + (1\text{-}F)^*[\text{Snags}]_t$$

That is, the number of live trees in any given year (time = t+1) equals the number of live trees from the previous year (time = t) multiplied by the yearly survivorship rate (S). The number of snags in any give year equals the number of live trees from the previous year multiplied by (1 - S), plus the number of snags from the previous year multiplied by (1 - F).

SnagPop requires users to enter data based on current stand conditions, such as the initial number of live trees per unit area and the initial number of snags per unit area. It also requires a decision on the number of years to run the simulation. In addition, the user needs to decide whether to use the live tree survival rates, snag fall rates, and stem decay occurrence provided for the four most important snag species, or to use local data if available. See Appendix 2 for details.

Conflicts with Other Ecosystem Management (EM) Objectives

We applied the snag retention and recruitment prescriptions on several hypothetical situations (in different stand conditions and different VRUs). While in some situations the protocol appeared to work well, there was an equal number of situations where snag recruitment prescriptions appeared to conflict with EM objectives.

As an example of scenarios in which the protocol worked well, consider a young 100-year-old stand of ponderosa pine, in VRU cluster 1, with no existing snags (not atypical of westside, low elevation situations on the Lolo and Bitterroot National Forests). The recruitment model suggests at least 30 ponderosa pine be retained for long-term recruitment. Typical EM prescriptions might involve commercial thinning and prescribed burning. Conflict? None whatsoever.

However, consider the next example: A 100-year-old Douglas-fir stand, in VRU cluster 1, with no existing snags (again, not atypical for westside situations). In this case, the protocol suggests retaining 40-60 Douglas-fir per acre for long-term snag recruitment. Typical EM prescriptions might involve regeneration, burning, and planting to ponderosa pine. Recognizing this apparent conflict, what takes precedent? This would appear at face value to place snag recruitment at odds with EM objectives.

Consider another example in different VRU cluster: A 100-year-old Douglas-fir, subalpine fir, and lodgepole pine stand in VRU cluster 4 with a good mix of existing snags (typical across western Montana and northern Idaho). In this case, retaining existing snags is a the obvious choise. However, recognizing there are larch (an important snag component of VRU cluster 4), what efforts should be made to regenerate larch, *versus* recruiting Douglas-fir and subalpine fir snags?

The snag protocol team concluded that in general, EM objectives that manage closer to historical conditions, including the retention/recruitment of large, seral trees, should generally take precedent over snag-recruitment objectives when desired seral species are missing from the landscape.

Here is rationale for that recommendation:

1) Categorically, large diameter, seral conifer species have declined across their range (Arno et al. 1995, Hann et al. 1997, Smith 1999). Where such large diameter, seral species (live and dead) still occur, aggressive actions should be taken to protect large diameter, seral snags and allow for longterm recruitment of large diameter, seral snags from surviving seral trees on the site.

2) In situations where large diameter, seral trees are *missing*, they cannot be restored without aggressive treatments. Retaining large numbers of live, climax recruitment trees could preclude EM treatments. More importantly, doing so would compromise the long-term recruitment of desired seral snags on the landscape.

3) The conclusions of the team were:

a) Protect those high value snags wherever they occur;

b) Recruit high value snags from the existing mix of live trees when available;

c) When desired seral species are unavailable, be willing to trade off the recruitment of less desirable climax snags if retaining those trees conflicts with the long-term recruitment of desired snags (i.e., don't worry about losing live grand fir if it allows for larch reestablishment).

d) Such decisions should be made over large landscapes. When all things are equal, managing snag recruitment in the long run to desired species probably should take precedent over simply retaining high numbers of snag recruitment trees of a marginally valuable species.

Creating snags

Snags can be created to compensate for past management actions that left too few snags or the wrong species, sizes, stages, or quality of snags in an area. Any snag-creation technique will be quite labor-intensive and should be considered for use in emergencies where the current and future snag outlook is bleak. Several techniques have been or are being tested for creating snags from living trees.

Not all snags are equal, and the cause of mortality has a lot to do with the quality and longevity of the snag. Snags caused by heartrot are valuable because they maintain a strong root system while providing heartwood for excavation by woodpeckers and nuthatches. On the other hand, trees killed by root disease have a short lifespan as snags.

Bull and Partridge (1986) investigated six methods of killing ponderosa pines. They learned that topping trees with either a chainsaw or explosives produced snags that stood the longest and received the greatest nest use by woodpeckers, compared to girdling, fungal inoculation, and attracting beetles by using pheromones. These latter techniques did not consistently kill the tree.

Topping trees is costly, but more importantly is risky and subject to OSHA regulations. Girdled trees (removing a broad band of bark) and using silvicides resulted in snags that fell over too quickly to provide wildlife nest trees.

The Forest Service is testing inoculation of fungi into ponderosa pines, larch, Douglas-fir, and other species. The fungi being tested would cause heartwood decay. Parks et al. (1996 a, b) used a new method of inoculating live trees with decay fungi. Six years after inoculation of 60 living western larch, 14% contained woodpecker cavities near the point of inoculation. These trees may remain alive for decades with a pocket of decay that woodpeckers can use for nesting. Trees may be logged next to these trees without safety concerns, and live trees are less likely than dead trees to be lost to firewood cutters (Bull et al. 1997).

Improving the longevity and quality of future ponderosa pine snags is another aspect of snag creation. The Forest Service is testing the role of multiple, low intensity fires in increasing the pitch content of trees. This higher pitch content may be the reason that ponderosa pine snags survive so long.

IMPLEMENTATION: ACHIEVING SNAG MANAGEMENT STANDARDS

Once snag retention levels are selected, there are still other issues to consider, including the scale at which to manage snags and recruitments, how to deal with on-the-ground conditions that don't fit into VRU groupings, and how to overcome the many obstacles to retaining snags.

Scale at which to Apply Snag Retention and Snag Recruitment Prescriptions
Identifying the appropriate scale at which to manage for snags is important. This is because of the following existing conditions:

1) Snag occurrence is highly variable across the landscape;

2) In developed landscapes, monitoring data have consistently shown that snag densities are severely reduced from historical levels due to logging; and

3) In all landscapes, the recruitment of large diameter, durable snags such as western larch, western red cedar, ponderosa pine, and eastside Douglas-fir, is severely compromised due to fire suppression.

For example, in stand-replacing fire regimes (VRUs 4, 5, and 6), it seems at first to be logical to conclude that it is normal for large percentages of the landscape to have no snags for significant periods, because of the "pulse" nature of snag occurrence in those fire regimes. Consequently, managers may adopt a philosophy of "it's OK to not provide for snag retention or recruitment on some acres in landscapes dominated by VRUs 4, 5, or 6." However, because of the conditions listed above, it is more appropriate to manage snags at the following scales:

- The objectives for snag retention and recruitment should be ASSESSED at the WATERSHED scale (6th code HUC or larger);

- Snag retention and recruitment prescriptions should be APPLIED, where possible, at the STAND scale; and

- The success of snag retention and recruitment should be MEASURED at the WATERSHED scale (6th code HUC or larger).

This means that snag retention and recruitment, at the prescribed levels for the appropriate mix of VRUs, should be applied aggressively on all stands where it is possible to do so, given other management objectives, so that the goals at the watershed scale ultimately can be met.

Selecting VRU classes
Any vegetative grouping represents an average set of conditions, but often never perfectly represents existing on-the-ground situations. When trying to decide which VRU cluster best represents a given situation, and therefore which set of snag management recommendations to apply, managers will invariably find situations in which on-the-ground conditions do not exactly fit any VRU cluster.

Here are some examples and possible solutions:

Example 1. You have warm, south-facing Douglas-fir/white pine/western larch communities with scattered subalpine fir in the understory. Older larch trees show multiple fire scars suggesting a mixed fire regime indicative of VRU Cluster 3 (see "Snag Management Recommendations by VRU Cluster"). The presence of subalpine fir suggests VRU Cluster 4. This raises the dilemma of whether VRU Cluster 3 or 4 best reflects snag availability over time.

Solution 1: While the subalpine fir habitat type series indicates VRU Cluster 4, the presence of fire-scarred larch indicates that the stand obviously is functioning under a mixed fire regime. Snags in the large diameter class occur as scattered, persistent individuals. Smaller snags may occur periodically at high densities with mixed severity burns. The snag standard for VRU Cluster 3 best reflects the stand's snag availability over time.

Example 2. You have cold, dry, high elevation lodgepole pine communities with scattered Douglas-fir. Lodgepole pine and Douglas-fir show evidence of being *mixed age* and have scattered fire scars indicating a history of mixed severity fires or low intensity bark beetle attacks. The habitat types suggest VRU Cluster 5, but the presence of mixed-aged Douglas-fir and lodgepole pine does not fit any of the seven VRU Clusters. These conditions may be common in the extreme upper Clark Fork drainages or on the east front.

Solution 2: As in the first example, the subalpine fir series suggests VRU Cluster 4. Clearly, however, the mixed age stand suggests that, while high numbers of snags may occur as a "pulse" after a stand-replacing event, they more typically occur as scattered individuals after beetle attacks or low/moderate intensity fires. VRU Clusters 3 and 4 do not fit because of the lack of larch, so there is really no VRU Cluster that fits perfectly. In this case, the snag densities for VRU Cluster 3 may be an appropriate target, but the recruitment numbers may need to be adjusted to reflect the reduced lifespan of lodgepole pine or Douglas-fir snags.

Using this snag protocol should involve an adaptive approach to local conditions based on a scientific understanding of the disturbance ecology involved, rather than blindly following the established VRU Clusters/snag retention and recruitment standards given in "Snag Management Recommendations by VRU Cluster."

Obstacles to retaining existing snags

Snags are, relative to live trees, naturally short-lived objects. We expect them to fall, but there are many factors in a managed forest that increase their likelihood to fall. These are: removal during timber harvest because of risk to woodsworkers; fire (planned or not); removal for firewood; fire suppression activities; and salvage of burned or insect-infested forests.

Removal during timber harvest

The Occupational Safety and Health Administration (OSHA) has issued requirements to protect timber workers from hazards created by danger trees. The application of OSHA standards is not discretionary and takes precedent over Forest Service snag guidelines where they disagree or differ. The increased awareness and role that OSHA requirements play in timber harvest activities must be considered and used when planning vegetation treatments and snag retention/management. The consequences of not doing so are grave. The Forest Service was held accountable on two recent Northern Region court cases involving one death and one serious injury from danger trees.

The Federal Register states that each "danger tree" be felled, removed, or avoided, and that a two tree-length influence area around the tree be included for treatment along with the specific tree (OSHA 29 cfr 1910.266. Logging Operations. amended by 60 Federal Register 47035, Sept. 8, 1995). OSHA defines a "danger tree" as "a standing tree that presents a hazard to employees due to conditions such as, but not limited to, deterioration or physical damage to the root system, trunk, stem, or limbs, and the direction and lean of the tree."

OSHA specifically cites snags as "danger trees." During discussions with OSHA representatives in 1995, it became apparent that the identification of "danger trees" and the designation of avoidance zones around such trees, is more flexible than the Federal Register implies. OSHA representatives specifically discussed the need to "apply local knowledge and common sense to danger tree situations." Danger trees found by the Forest Service or the operator must be evaluated and a decision made. However, the safety risk presented by a "danger tree" varies by the condition of the tree and the type of human activity near the tree.

Because of the complexity of the issue, a group of corporate, state, and federal agencies from Montana and Idaho met with OSHA representatives in 1995 and published "Risk Assessment for Identifying Reserve Trees" (Intermountain Forest Industry Association et al. 1995). This publication categorizes snags by their risk class, and identifies situations under which a given snag would or would not be considered a danger tree, and if so, how to decide appropriate avoidance zones. The key point of the document is that under given conditions, not all snags constitute a severe hazard. As a supporting management tool, the Northern Region produced a snag training curriculum in 1996 that used a canned slide program, which was mailed to all National Forests. The curriculum focused on how to identify the relative "value" of a given snag to wildlife, compared against the "risk" that snag posed to woodsworkers. Because not all snags are equal in terms of value to wildlife and risk to humans, it was felt that if woodsworkers were better informed, they could make better decisions in terms of protecting high-value wildlife snags, and avoiding high-risk situations.

In general, the following elements should be considered when planning for snags in/around harvest activities:

- The document "Risk Assessment for Identifying Reserve Trees" should be used as the tool for identifying danger trees.

- The decision to cut or leave each danger tree identified will be made by the purchaser/operator.

- The Forest Service administrator will document actions taken by the purchaser to remove/avoid danger trees, particularly when those actions are inconsistent with the designation or actions specified in "Risk Assessment for Identifying Reserve Trees."

- While the decision to cut or leave danger trees is up to the operator, it should be recognized that failure to appropriately address danger trees involves potential fines from OSHA, and liability for injury for both the Forest Service and the purchaser.

- Expect that most danger trees will be removed if they occur near landings, roads, cable corridors, or other areas where people are on the ground and unprotected.

- The discretion to leave danger trees is considerably increased when harvest activity is carried out using mechanized equipment where operators are in protected cabs.

- Other recommendations that can help retain snags include snag-protection measures during broadcast burning in harvest units (use of foam, hose lines, or shelters; pulling slash away from snags; precluding portions of units with high densities of snags); protecting snags from cable damage by leaving more green trees; and training of timber sale markers and sale administrators.

- Snags felled for safety purposes should be left on site as they are valuable as down woody debris.

To maintain snags in timber harvest areas, consider reserve areas in and around harvest units, and/or require use of mechanized equipment to maintain more discretion to retain snags within harvest units.

Firewood removal

Forest plans do not address firewood harvest outside timber sale areas. Firewood harvest has had a significant deleterious effect on snags for the following reasons:

- Firewood gatherers now have the technology (cables, ATVs, oversnow vehicles) to harvest firewood farther from roads as the nearer "easy wood" has been depleted.

- The rate of harvest has been higher than is sustainable.

- The effect of firewood removal was underestimated because plans used incorrect assumptions about woodpecker territory size as the basis for snag standards.

- In general, Forests have allowed firewood harvest anywhere except where special orders close specific areas.

Field data collected from 1991-1997 on the Fortine District of the Kootenai National Forest show the effects of open roads on the density of snags available in various VRUs. In the drier VRUs, there were more than 4 snags/acre outside a 200' buffer surrounding all open roads, while within the 200' buffer there were fewer than 2 snags/acre. In the moist VRUs, there were from 7.6 to 14.5 snags per acre outside the 200' buffer, and between 3 and 7 snags per acre inside the buffer. In the cold VRUs, there were 6 to 7.6 snags per acre outside the buffer, and 6 to 13 snags per acre inside the buffer. The results within the latter VRUs (similar densities to greater densities within the buffer) are not surprising, given that these colder types tend to be at higher elevations and less accessible than the warmer and drier types.

To maintain the right kinds of snags in the right quantity and in the right places:

- Limit harvest to certain species of trees where retention of particular species is important (e.g., larch or ponderosa pine snags are preferred over lodgepole pine or grand fir snags).

- Consider green tree removal instead of snags, where appropriate.

- Require a snag inventory and vulnerability analysis before opening an area to firewood harvest. The assessment should consider the landscape scale.

- Limit firewood removal to downed wood.

- Close roads using physical barriers to limit unauthorized removal of snags.

- Include the cost of road maintenance and firewood program administration in the cost of the permit.

- Raise the priority for enforcement and administration.

- Heighten awareness of the importance of snags among Forest employees and the public with the aid of Public Affairs personnel and interested non-governmental organizations.

- Limit access into open areas to periods when administrators are present to monitor the removal of wood. When specified snag quotas are met, close the area.

- Close the Forest to firewood harvest except for designated open areas.

Prescribed fires; wildland fire use (prescribed natural fires)
For snag management, the goals in prescribed fires or in wildland fire use are to: 1) protect existing snags, 2) protect large green trees, and 3) create conditions that harden ponderosa pines and western larch where they occur. There are many options available, depending on the site. Whoever is preparing the prescription or wildland fire use plan should keep these three goals in mind and seek opportunities to meet them.

Some techniques used include:

- Reducing fuel loads in the stands by thinning, or slashing/thinning to remove young trees that provide a fuel ladder;

- Pre-treating areas within a large prescribed burn by burning-by-hand ahead of time to reduce the intensity of the larger burn;

- Protecting high value areas, such as old-growth forests, from wildland fire by burning-by-hand ahead of time or building a fireline;

- Timing the burn to occur when the sap is not on the surface of the bark. If sap is running and is on the surface, the bark gets too hot and burns. There are only a few critical periods when it is safe to burn if the goal is to harden snags and decrease mortality from the fires. An early spring burn, between green-up and sap-running, is one such period;

- Allowing some intentional slop-over outside the perimeter. Perimeter scorching adjacent to clearcuts can create snags to compensate for lack of snags within the clearcut;

- Clearing dead woody debris and dead needles around snags or large green trees (clearance distance varies by steepness of slope and other factors. For example, a clearance within 2-3 feet may be adequate on flat areas while 15-20 feet downhill may be needed on steep slopes); and

- Using fire shelter material around the base of trees or snags.

The last two techniques are very labor-intensive and their use would be restricted to situations where there are very high value snags and green trees that must not be lost from the stand.

Fire suppression activities
The main goals in fire suppression do not include snag protection. However, there are some opportunities to protect snags. For example, mop-up could focus on the edges of the burn, leaving behind smoldering trees and snags in the middle of the burned area.

Today's fire suppression is more flexible than in the past. Where values are low (e.g., where buildings or other high value resources are not in jeopardy), fire fighters can pick the best ridge at which to stop the fire. This would allow it to burn through an area, creating snags and hardening ponderosa pines and western larch, rather than trying to stop the fire as soon as possible. This flexibility in where to locate fire lines could also be used to place them where the dropping of higher value snags for safety reasons should be avoided.

Salvage of burned or insect-infested forests

Wildfire has been an important ecological process in shaping landscapes and bird distributions of western North America (Hejl 1992, Hejl 1994, Saab and Dudley1998). Some bird species flourish in burned habitats, especially woodpeckers, flycatchers, and seed-eating species. Standing, fire-killed trees provided nest sites for nearly two-thirds of 31 species that were found nesting in burned sites in various forest types in western Montana (Hutto 1995). Forest conditions before a fire, especially the presence of snags, are important in determining use of the area post-fire by cavity-nesters (Hutto 1995, Saab and Dudley 1998). Wildlife use existing snags and fire-killed trees for feeding, nesting, or both. Management for snag recruitment (particularly broken-topped snags) in green forests will provide nest trees during the first few years after a wildfire when other trees are difficult to excavate (Saab and Dudley 1998).

In western Montana conifer forests, ponderosa pine, western larch, and Douglas-fir are especially important foraging substrates for birds (Hutto 1995). Bird species differ in the microhabitats they occupy within a burn (Hutto 1995, Saab and Dudley 1998), and salvage methods that "homogenize" the stand structure will not supply the needed range of microsites (Hutto 1995). One possible solution is to take trees from one part of the burn and leave another part untouched (Hutto 1995). This would be the safest method for woodsworkers, as burned forests are notoriously hazardous.

Saab and Dudley (1998) recommended a different solution for salvage programs for ponderosa pine/Douglas-fir forests of southwestern Idaho. They recommended providing a range of stand conditions characteristic of what would support populations of black-backed and Lewis' woodpeckers. This range of conditions would likely incorporate local habitat features necessary for successful nesting of other members of the bird community. Unlogged units with high tree densities (≥50 snags greater than 9" dbh per acre) of relatively small, hard snags were typical of black-backed woodpecker nest sites. Partially logged units (averaging 25 snags greater than 9" dbh per acre) with clumps of relatively large, soft snags characterized Lewis' woodpecker nest sites. They also recommended retaining clumps of trees rather than uniformly distributed trees, but could not provide recommendations on clump size. They also recommended leaving more large snags (>20" dbh) than usual because these have greater longevity than smaller snags.

MONITORING AND INVENTORY

There is need for an inventory and monitoring program that could be used to provide an inventory of snags for adjusting recommended standards, and to monitor for compliance with the standards. Such a program should improve upon the current FIA.

Inventorying Snags to Adjust Recommended Standards
Bull et al. (1997) describe inventory techniques, including one developed by Bate et al. (1999). The following abstract summarizes the technique developed by Bate et al. (1999):

> "We provide efficient and accurate methods for sampling snags and large trees on a landscape to conduct compliance and effectiveness monitoring for wildlife in relation to the habitat standards and guidelines on National Forests. Included here are the necessary spreadsheets, macros, and instructions to conduct all surveys and analyses pertaining to estimation of snag and large tree densities and distributions at the subwatershed scale. The methods focus on optimizing sampling effort by choosing a plot size appropriate for the specific forest conditions encountered. Two methods are available for density analysis. Method one requires sampling until a desired precision level is obtained for a density estimate. Method two is intended for use in areas that have low snag densities compared to Forest plan targeted densities. After taking a minimum of 60 samples, one may test for a significant difference between the estimated and targeted densities. In addition, data can be used to calculate a distribution index. The value obtained from the distribution index indicates whether the current distribution of target snags and large trees across a subwatershed is adequate to meet the habitat needs of territorial cavity-nesters and other wildlife species. Wildlife use also may be evaluated."

Monitoring to Determine Compliance with Snag Retention Standards
The method developed by Bate et al. (1999) may also be used to monitor compliance with snag retention standards. The Lolo National Forest developed a different snag-monitoring methodology to determine the success of snag retention efforts. They monitored snags during different phases of logging to determine at which phase they most risked losing snags and recruitments. This allowed them to focus on those phases to increase their success in meeting their Forest Plan Standards. The protocol is given below:

One 0.2-ac plot should be established for every two acres in a monitoring unit. Thus, a 30-ac unit would be assigned 15 0.2-ac plots. Plots should be established by putting a transect through a unit with plot centers at roughly 2-chain intervals. Transects should be run with a random compass direction.

Data collected at each plot should include:
Site name
Unit number
Type of marking used
Habitat type (averaged to habitat group for the unit)
Aspect
Slope
For each snag > 10" dbh and >15' height:
- Marked/unmarked
- Species
- Height
- Dbh
- Presence of holes <2" diameter

Presence of holes $\geq$2" diameter
Broken top or not
Conks or not
Hard/soft

For each live tree marked as a potential live replacement

Species
Height
Dbh
Presence of holes <2" diameter
Presence of holes $\geq$2" diameter
Broken top or not
Conks or not
Heartrot or not
Waning top/vigorous

Collection of these data provide, for each unit sampled, an average number of snags existing on the site, an average number of snags marked for retention, and an average number of live replacements either left for that purpose or available for live replacements at final removal. The Lolo National Forest compiled data to represent the percent of the minimum number of snags needed to meet the Lolo Forest Plan Standard. A score of 35%, for example, meant that the unit sampled retained only 35% of the snags required in the Forest Plan Standard. Often, live defective trees were left in lieu of adequate snags; these were counted as snags.

Updating the FIA database

The Northern Region is developing a multi-scale ecological system inventory and monitoring program. The vegetation portion of this is being pilot tested during FYs 1999-2001, to determine appropriate mapping protocols, ground survey design protocol, and plot design protocol. The plot design being tested in the pilot effort on the Idaho Panhandle NF is an augmented FIA design. This design will have 4 sub-plots located within a 1-hectare macro plot. Each of the 4 sub-plots will have a 1/100th acre fixed plot for tree regeneration, a 1/24th acre plot where all trees live and dead will be inventoried, a 1/4 acre plot where trees live and dead over 21" will be inventoried, while on the macro 1-hectare plot only live and dead trees over 32 " will be tallied. This sample design will thus inventory 21"+ snags on one acre (four 1/4 acre plots), and snags over 32 " on the 1-hectare plot, with small snags recorded on the four 1/24th acre plots. This design, if deemed effective through the pilot study, will then be recommended as the plot design for the long term Inventory and Monitoring program in the Region. The survey design could potentially include approximately 10,000 to 15,000 plots in Region One, of which 80% would likely be in forested settings.

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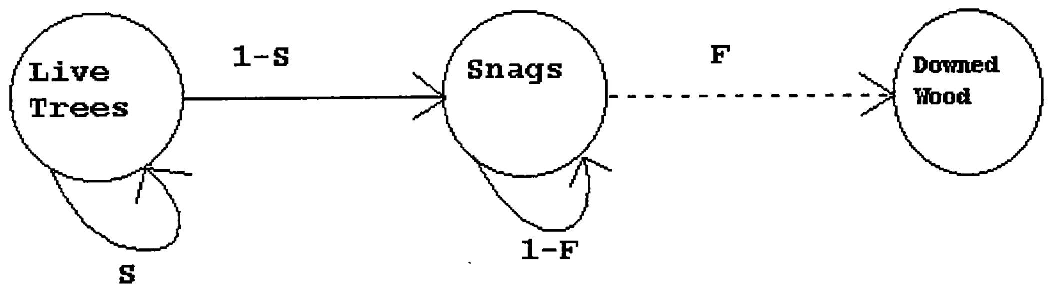
Appendix 1. Forest Inventory and Analysis (FIA) snag data from lands managed by the Lolo, Bitterroot, and Kootenai National Forests, Montana Department of Natural Resources, and private industry. Data were provided by Rich Harris, May 7, 1998. Highlighted boxes are those used for determining recommended snag densities.

VRU Cluster	Total # Sample Plots	Structure Class	# Plots by Structure Class	Average # small snags per acre (4.0-10.9" dbh)	Average # medium snags per acre (11.0-19.9" dbh)	Average # large snags per acre (20.0"+ dbh)
1—Warm, dry ponderosa pine, Douglas-fir	91	1--single cohort Ignore as this cohort is of a turn-of-the-century origin from fires.	33	13.3	3.5	1.0
		2--two-story unlogged	19	5.7	2.0	0.6
		3--multi-storied unlogged	27	7.9	5.4	1.6
		4—patchy distribution	12	5.7	2.8	0.2
2—Cool Douglas-fir, warm grand fir on gentle slopes	58	1—single cohort	27	15.6	5.8	5.1
		2—two-story unlogged	10	18.4	3.4	0.8
		3—multi-storied unlogged	17	17.3	5.4	4.2
3—Cool Douglas-fir, warm grand fir on steep slopes	167	1—single cohort	71	17.6	2.8	0.8
		2—two-story unlogged	38	9.5	6.3	1.5
		3—multi-storied unlogged	63	9.1	4.5	0.8
4—Cool, wet, and dry spruce, grand fir, hemlock, and subalpine fir	551	1—single cohort	203	31.3	5.4	0.8
		2—two-story unlogged		23.0	7.0	1.4
		3—multi-storied unlogged		21.9	10.0	1.8

5—Low elevation cedar, hemlock	52	1—single cohort	14	25.0	[redacted]	[redacted]
		2—two-story unlogged	8	13.5	[redacted]	[redacted]
		3—multi-storied unlogged	30	27.0	[redacted]	[redacted]
6—High elevation spruce/fir/lodgepole pine	36	1—single cohort	12	26.5	[redacted]	[redacted]
		2—two-story unlogged	6	12.3	[redacted]	[redacted]
		3—multi-storied unlogged	16	13.3	[redacted]	[redacted]
7—Whitebark pine/limber pine	87	1—single cohort	20	24.2	8.7	[redacted]
		2—two-storied unlogged	22	33.4	19.9	[redacted]
		3—multi-storied unlogged	45	22.6	17.2	[redacted]

Appendix 2. SnagPop--A Stage-Structured Population Model for Snags

Model Summary:
SnagPop is a matrix population model that plots the number of live trees and number of snags per unit area over time. The life cycle graph below represents the model.



There are two stages in the life cycle of a snag represented in the model: live trees and snags. Live trees either remain live trees or become snags. Snags either remain snags or fall and become downed wood. Downed wood is implicitly modeled as snags that do not survive. Live trees survive at a given survivorship rate (S) and die and become snags at the rate (1- S). Snags fall at a given rate (F) and remain snags at the rate (1-F).

SnagPop uses the following equations to calculate the number of live trees and snags each year.

$$[\text{Live Trees}]_{t+1} = S*[\text{Live Trees}]_t$$

$$[\text{Snags}]_{t+1} = (1-S)*[\text{Live Trees}]_t + (1-F)*[\text{Snags}]_t$$

That is, live trees in any given year (time = t+1) equal the number of live trees from the previous year (time = t) multiplied by the yearly survivorship rate (S). Snags in any given year equal the number of live trees from the previous year multiplied by (1 - S), plus the number of snags from the previous year multiplied by (1 - F).

Running the Model:
The SnagPop model and documentation are available on the Northern Region home page on the Intranet. From the home page, proceed to RO Units, then WWFRP, Wildlife Ecology, SnagPop.

The input parameters for SnagPop are:

1 - Initial number of live trees per unit area. The model lumps all live trees into one category, so the number of live trees entered here should be the number in a single cohort of even-aged trees. This is an obvious simplification of reality, but we found little data to estimate survivorship of species by size class and we are really interested in modeling the persistence of large snags in time. If you want to model large snags in time, you can enter the current number of large trees (>20" dbh). The unit area can be any value, but probably is best viewed at the stand level.

2 - Annual live tree survival rate. Survival rates for 4 tree species are listed above. These rates are based on large trees and therefore best used with an initial number of large trees only, rather than a mix of small trees and large trees.

3 - Initial number of snags per unit area. This value is the number of snags currently standing, if any. Once again, the unit area is best viewed at the stand level.

4 - Annual snag falling rate. Falling rates for 4 tree species are listed above.

5 - Stem decay multiple. This fraction reduces the number of snags remaining by eliminating those without sufficient stem decay for use by cavity nesters. We are currently using a fraction 1.0, thus considering all remaining snags in the model as useful to cavity nesters.

6 - Number of years to run the simulation. This is simply the number of years you wish to run the model.

Enter initial live tree and snag numbers as integers, and enter rates as decimal fractions (i.e., 0.998 for a 99.8% survival rate). After entering all parameters, click on the Plot Graph button at the top of the screen. SnagPop will plot the number of live trees and snags in time and print out the final number of live trees and snags.

Description and Data Sources for SnagPop Variables

Live Tree Survivorship Rates: Survivorship is the predicted rate at which live trees of a given species die. Survivorship rates are included for four species in Table 2.

Table 2. Average annual survivorship rates for four species of coniferous trees in the Northern Region.

Species	Average Annual Survival Rate, Idaho and Westside Montana	Average Annual Survival Rate, Eastside Montana
Ponderosa pine	0.998 (500 years)	0.998 (500 years)
Douglas-fir	0.995 (200 years)	0.998 (500 years)
Western larch	0.998 (500 years)	---
Western red cedar	0.999 bottomlands, 0.998 uplands (1000 years)	---

Data Source and Interpretation- Survivorship rates for large diameter ponderosa pine (0.998) came from FIA data (Harris 1998). Survivorship rates for other species listed above are based on the ponderosa pine rates and professional judgment. Bull et al. (1980) used survival rates of 0.9959 for large (>20" dbh) ponderosa pine. The survivorship rate of 0.998 for westside Montana ponderosa pine means that in any given year, 998 trees out of 1000 will survive; two/year will die. The last two die at year 500. For westside Douglas-fir the rate is 0.995. This means that in any given year, 995 trees out of 1000 will survive; five/year will die. The last five die at year 200. By comparing the two rates, it's obvious that Douglas-fir on the westside is significantly shorter-lived than ponderosa pine. A different situation exists on the eastside where Douglas-fir grows on droughty sites, and survives periodic underburns much like westside ponderosa pine. The extreme situation represented in the table is western red cedar, which can live 1000 years, giving it the highest survivorship rate of the four species assessed.

Snag Fall Rates: The snag fall rate is the rate at which snags of a given species fall. Snag fall rates are included for four species in Table 3.

Table 3. Fall rates for snags of four species of coniferous trees in the Northern Region.

Species	Fall Rate (snag life expectancy), Idaho, Westside Montana	Fall Rate (snag life expectancy), Eastside Montana
Ponderosa pine	0.02 (50 years)	0.02 (50 years)
Douglas-fir	0.05 (20 years)	0.02 (50 years)
Western larch	0.015 (75 years)	---
Western red cedar	0.01 bottomlands, 0.02 uplands (100 years)	---

Data Source and Interpretation--Snag fall rates for ponderosa pine are from Bull (1983). Snag fall rates measured by Dahms (1949) over a 22 year period further support Bull's fall rates. Fall rates for other species listed above are based on the ponderosa pine rates and professional judgment. The fall rate 0.02 for westside Montana ponderosa pine means that in any given year, one snag out of 50 will drop. The last snag will hit the dirt at year 50. For westside Douglas-fir the rate is 0.05. This means that in any given year, one snag out of 20 will fall. The last snag will hit the dirt at year 20. By comparing the two rates, Douglas-fir snags on the westside are significantly shorter "lived." A different situation exists on the eastside where Douglas-fir grows on droughty sites, and the periodic exposure to nonlethal fires and pitch buildup gives it a snag fall rate comparable to ponderosa pine (0.02). The extreme situation represented in the table is the bottomlands western red cedar snags, which can stand for a century, giving them the lowest snag fall rate (0.01). There may be local data that provide more site-specific fall rates. If better data become available, we can adjust these fall rates.

There is a relationship of survivorship and fall rates to stem diameter and to exposure to fire. The snag fall rates predicted above can only be considered valid when dealing with large diameter snags greater than 20" dbh. Small snags fall at rapid and unpredictable rates (Lyon 1977). Smith (1999) determined that large snags that have stood for long periods of time invariably were very old, and probably had been exposed to nonlethal fires many times while they were living. Snags, even large ones, that were not exposed to nonlethal fires fall very rapidly. Consequently, the fall rates listed above should only be considered valid when dealing with trees that are old enough to have been exposed to historic, nonlethal fires. Snags from trees killed by pine beetles also fall rapidly.

Sensitivity of the model-As Harris (1998) noted, small changes in the survivorship or fall rates have enormous changes in the outcome of the model. For instance, a change in fall rate from

0.02 to 0.05 increases the number of recruits needed *by 2.5 times* (see Mathematical Rationale below).

Stem Decay Multiple: McClelland (1977) and Bull et al. (1997) both discuss the high value of stem decays for nesting pileated woodpeckers. Consequently, stem decays should be *well represented* in the live recruitment population. We interpret "*well represented*" to mean no fewer than 1-2 live trees (of ponderosa pine, Douglas-fir, larch, or western red cedar, greater than 20" dbh) per acre within the live recruitment population.

Blakey Lockman queried the R1 Edit stand exam database, survey types 45-46, to identify levels of stem decay on all Forests in the Northern Region. The query only included trees >20" dbh. The results of that query are in Table 4.

Table 4. Stem decay rates for four coniferous species in the Northern Region.

Species	Stem Decay Rates
Ponderosa pine	4.3 to 10.8%[1]
Douglas-fir	7.4 to 14.9%
Western larch	9.0 to 21.8%[2]
Western red cedar	30.0 to 54.6%

[1] Excluding data from the Gallatin NF as it is on the edge of the range of ponderosa pine.
[2] Excluding data from the Helena NF as it is on the edge of the range of western larch.

The lowest level of stem decay is in ponderosa pine. Even at that low level, however, normal recruitment rates (see Mathematical Rationale below) would provide the required 1-2 recruitment trees/acre with stem decay. Of course in stands of Douglas-fir, western larch, or western red cedar, with higher levels of naturally occurring stem decays, the number of trees with decay would be much higher. These decay rates depended greatly on external indicators of decay that were detected in stand exams; therefore, there is likely to be more decay present than indicated by these percentages. For this reason, the stem decay rate coefficient in the model is set at 1.0, giving it no meaning in the model, because the data suggest stem decay rates are adequate to ensure that randomly selected, large live tree recruitments will contain reasonable amounts of stem decay after death. We retained the variable in the event that future data suggest stem decays need to be given more weight.

Mathematical Rationale for the Model

The rationale for the SnagPop interactive computer model is fairly simple. As an example, if we were to calculate the recruitment rate for a stand of pure westside ponderosa pine, we would go through the following steps:

1. The FIA prescriptions recommend 1-2 snags/acre for VRU Cluster 1 (ponderosa pine);

2. The survivorship rate for ponderosa pine is 0.998, meaning that they live for 500 years;

3. The fall rate for ponderosa pine is 0.02, meaning all snags hit the dirt at year 50;

4. Then using the simplest of logic, you need 10 times the number of recruits to maintain the prescribed level of snags, or 10-20 live recruitment trees/acre.

Obviously, it's much more complicated than that because often you're dealing with a *mix* of snags (Douglas-fir/larch or lodgepole pine/Douglas-fir for instance). Another common scenario is that a typical population of live trees may lack large trees. Consequently, the model must allow those trees to grow for a while to provide 20" dbh live trees to ultimately provide 20" dbh snags. Meanwhile, you lose some of those trees to natural mortality (reflected in the survivorship rates), and some of the existing snags fall (reflected in the fall rates). Consequently, the recruitment multiple (10 in the example above) is invariably higher in field situations.

We ran several "what-if" scenarios to see how many live recruitments might be needed within VRU Clusters 1, 2, and 3. When stands contained many large ponderosa pine or western larch, adequate snag recruitment trees could be provided *by retaining seed tree to shelterwood stocking levels* (these trees would, of course, be left for perpetuity). In VRU Cluster 4, the number of recruitments needed would be much higher (40-60+/acre). We also ran some "what-if" scenarios for VRU Clusters 2 and 3 dominated by fairly pure, older Douglas-fir (a fairly typical situation). This situation also required retaining large numbers of large diameter live trees (40-60+/acre) to meet long-term recruitment needs. This raises some questions about meeting other ecosystem management objectives (see Conflicts with other Ecosystem Management Objectives below).